

UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

GRAIN SORGHUMS

BY
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BULLETIN No. 278

April, 1917

Reprinted June, 1921

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY
1921

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INTRODUCTION

The transition from extensive to more intensive methods of farming, together with the rapid development of the livestock industry which has taken place in California during the past few years, has created a demand for crops which would produce a dependable quantity of grain and forage on the vast areas of unirrigated land during

the dry, hot summer months. The crops which have thus far shown the greatest promise in filling this demand are the grain sorghums. While they are by no means new crops in this state, they have been of relatively little importance agriculturally since their production has been confined largely to a few rather circumscribed localities. For this reason general information regarding their production is lacking, as is evidenced by the large number of inquiries received by this department during the past three or four years. It is, therefore, the purpose of this publication to set forth briefly the information which has been gathered through experimentation and observations, with the hope that it may be of service to the farmer who is contemplating the production of these crops.

HISTORY IN CALIFORNIA

The history of the grain sorghums in this state, as well as in the United States, dates back to 1874, when a small consignment of White and Brown Durra was brought to California from Egypt. They were taken to the interior valleys, where they at once demonstrated their ability to withstand the hot, dry California summer, and very soon became established as a permanent crop. The Kafirs were introduced from the great plains a few years later and were followed in 1886 by Milo, which was brought from Texas. The latter crop soon demonstrated its superiority over the earlier introductions, and quickly attained a prominent place among the grain sorghums, a position which it has held to the present day.

While the grain sorghums have not risen into prominence as have some other crops, there nevertheless, has been a normal and continual increase in their production. In 1899 the total acreage of grain sorghums in California was 20,218 acres, yielding 420,452 bushels of grain. In 1909 the acreage had increased to 44,308 acres, and the production to 938,049 bushels. Thus in ten years the acreage had increased 119.2 per cent, while the yield had increased 123.1 per cent. By 1919, 170,000 acres were grown with a production of 4,386,000 bushels, an increase in acreage over 1909 of 283.7 per cent and in production of 367.5 per cent. Especially worthy of mention is the development of the grain sorghum industry in the Imperial Valley, in which section sorghum is at the present time one of the leading crops. The counties leading in the production of grain sorghums in 1909 were Tulare, Stanislaus, Kings, San Joaquin and Kern, in the order mentioned the first three contained over one-half the total acreage of the state.

ADAPTATION

Climatic Requirements.—The grain sorghums are of tropical origin, attaining their maximum development in regions having high temperatures and relatively low humidity during the growing season. Most of the varieties seem to be very susceptible to low temperatures, a fact which might militate against their use in sections where the average daily temperature during the growing season is low, or in sections having wide daily temperature ranges. Experiments and observations in this state, however, would seem to indicate that they can be grown successfully in all the interior valleys, and under these conditions constitute a very commendable substitute for corn. They have not, however, given as good results along the coast except in the southern portion of the state, or at elevations above 5000 feet, though it is quite possible that varieties may yet be obtained which will give fair results even under these conditions.

Drouth Resistance.—All varieties of sorghums are drouth-resistant, and are considered among the surest of dry-land crops, though this quality is possessed to a greater degree by the grain sorghums than by any of the other types. Their ability to withstand drouth, however, is apparently due to their ability to make economical use of the water available rather than to their low water requirements.

While the grain sorghums as a class are comparatively shallow rooted, the roots are very much branched, completely filling the upper three feet of soil with a network of fine roots. This extensive root development, together with other physiological characteristics, enables them to utilize a larger proportion of the soil moisture than that used by most other plants. Furthermore most of the varieties are able to withstand a prolonged period of drouth without apparent injury.

Other things being equal, however, the yields obtained will usually be in direct proportion to the supply of moisture available. In many instances, with proper attention to details, good results have been obtained with a precipitation of eight to ten inches. When the precipitation is less than eight to ten inches, however, it is doubtful if paying returns can be obtained unless considerable moisture is carried over in the soil from previous seasons. With the annual precipitation greater than twelve inches good results can nearly always be obtained if proper precaution is taken to conserve the moisture.

Soil Requirements.—Grain sorghums may be grown on almost any soil that admits of ready cultivation. Like Indian corn, they prefer a sweet soil, loamy in character and high in fertility. Very sandy soils or very heavy soils are not desirable. In the former type difficulty is often experienced in storing sufficient moisture for the use of the crop.

Heavy soils, on the other hand, are difficult to handle, and are apt to be cold and in poor physical condition at the time for planting, which may result in a poor stand.

Soils containing alkali are also objectionable but the sorghums are more resistant to alkali than most field crops. Nevertheless, large amounts of soluble salts in the soil will exert an injurious effect upon the growth of the plants, thus decreasing the yield.

TYPES AND VARIETIES

The sorghums (*Andropogon sorghum*) include grain sorghums, sweet sorghums, broom corn, and probably also Sudan grass and Tunis grass, at least the relationship between the former and the latter two is very close. The division into agricultural groups or sub-species is based largely upon physical characteristics of the plants, and the purpose for which they are grown. Also rather closely related to the sorghums is Johnson grass (*Andropogon halipensis*), a well known weed pest in some portions of the state.

While the sorghums are self-fertile, a great deal of natural hybridization takes place under normal conditions, not only between varieties of the same type but between the various types. When different varieties of the sorghums or any of the sorghums and Sudan or Tunis grass are grown in adjacent fields, a large number of natural hybrids usually appear. This fact is significant as it shows the necessity of keeping the seed plots isolated in order to maintain a pure strain. Hybrids with Johnson grass, on the other hand, are apparently rare.

The grain sorghums are divided into groups as follows: Durras, Kafirs, Kaoliangs, and Shallu, this division being made largely on head and plant characteristics. The Durra group includes White and Brown Durra, Feterita and the Milos. As a whole they are early maturing, with rather short, dry, leafless stalks. The heads are thick, compact, ovate or egg shaped and may be either erect or pendent, depending upon the variety and cultural conditions. The White and Brown Durras, more commonly known as White Egyptian or Jerusalem corn and Egyptian corn, have very dry, leafless stalks, with large, chaffy pendent heads and decidedly flattened seeds. The white-seeded variety shatters readily and is also often attacked by the birds. It is, however, the earliest maturing of the Durras.

Feterita, a more recent introduction which has created considerable interest during the past few years, is rather tall, moderately leafy, with erect heads and plump bluish-white seed. It is early

maturing and apparently equally as drouth-resistant as the other forms, but its seed is rather soft and of low vitality so that difficulty is often experienced in securing a good stand, especially in heavy or cold soils.

The Milos have somewhat finer, juicier stems, are more leafy, and stool or sucker more profusely than the other Durras. The heads of the Milo may be either erect or pendent, with large, protruding seeds. The Standard Milo and the Dwarf Milo are both yellow-seed forms, the latter being a selection of the former, having been developed for its shorter stems, earlier maturity and greater drouth-resistance. The White Milo resembles the Standard Milo except that it has white seed instead of yellow.



Fig. 1.—With a good stand and on strong land dwarf Milo will produce abundant yields of both grain and forage. Note the taller hybrids in the background.

The Kafir group includes all the various varieties of Kafirs, most of which produce rather large, leafy, slightly juicy stalks and are rather late maturing. The Kafirs are further characterized by having erect, slender, cylindrical heads with somewhat smaller seeds than the Durras. Of this group the principal variety grown is the Black Hull White Kafir, though within recent years an Early Black Hull and a Dwarf Black Hull Kafir, have been developed by selection from the former type. The latter varieties resemble the former except that they are both shorter in stature and earlier maturing. The other varieties of Kafir, including the White, Pink and Red, both because of the poor yield and late maturing, have ceased to be important.

The Kaoliangs or Chinese sorghums have not been grown commercially in California as yet. As a class they are early maturing and possess small, dry, leafless stalks and erect, open heads. It is believed that they require less heat than either the Kafirs or the Durras and if this be true they might be of value at higher elevations or in sections where the growing season is too cool or too short for the latter types. As but little is known regarding their agricultural value, limited trials under the conditions mentioned are recommended before their production on a large scale is attempted.



Fig. 2.—Feterita is not so resistant to adverse moisture and temperature conditions at the time of germination as other grain sorghums, but when a good stand is secured the yields are high.

Shallu, more commonly known as Egyptian wheat, differs from the former types in that it has rather large, dry stalks, very loose open heads and small, hard seeds, which, however, possess a high degree of vitality. Because of the latter character it is usually easier to secure a good stand with Shallu on soils that are cold and wet or of poor physical condition than with any of the other varieties.

In order to secure some information as to the relative value of the different varieties as grain crops, a variety test was begun at the University Farm at Davis in 1913. This test included not only

the more common varieties but some of the more recent introductions as well. The yields obtained during the years 1913 to 1916 are given in Table I.

TABLE I
VARIETY TRIALS WITH GRAIN SORGHUMS
DAVIS

C.I. No.	Variety	Yields per acre, pounds				
	<i>Durras</i>	1913	1914	1915	1916	Av.
332	Dwarf Milo	2305	4450	5031	2214	3575
234	Standard Milo	1492	3480	4830	2362	3041
.....	White Milo	.....	2860	4693	1974	3176
.....	White Durra	223	940	2520	378	1015
.....	Brown Durra	2813	3200	5071	1521	3151
182	Feterita	3164	2380	3139	1953	2909
<i>Kafirs</i>						
340	Dwarf Black-Hull	959	2220	3209	1460	1962
472	Early Black-Hull	618	2450	2520	483	1518
185	Black-Hull White	64	2600	1968	463	1274
342	White Kafir	.....	1400	1533	1092	1342
34	Red Kafir	128	1250	1434	315	782
.....	Pink Kafir	.....	2475	2667	504	1883
<i>Kaoliangs</i>						
310	Brachets Black-Hull	.....	.....	4662	777	2520
272	White Kaoliang	.....	.....	1071	325	698
170	Manchu Brown	.....	2000	4436	777	2404
171	Brown	.....	3700	4284	903	2962
.....	Shallu	.....	4200	4609	1816	3542

In studying the data given in the table it will be noted that there is considerable difference between the yields of any single variety for the different seasons. The relatively low yield of all varieties in 1913 was due to drouth, the total precipitation being less than nine inches. In 1916 the yields were also rather low. This, however, was due primarily to the poor stand obtained in most cases. In the absence of spring rains the soil became very dry before planting time, rendering the preparation of a good seed bed almost impossible. The conditions during the two seasons 1914 and 1915, on the other hand, were good and the results obtained were excellent.

Considering the average yield of the varieties by groups, it will be noted that of the *Durras* the highest yield was produced by Dwarf Milo, with 3575 pounds per acre, followed by White Milo, Brown Durra and Standard Milo, respectively. Attention is called to the fact, however, that the White Milo was not grown during the dry

season of 1913, but was grown only during the three most favorable seasons, and that the yield during these three seasons was lower than the yield of either Brown Durra or Standard Milo.

The lower yield of Feterita as compared with the former varieties is unquestionably due, in nearly all cases, to a poor stand. Nevertheless this factor is an important one when considering the relative merits of the different varieties. The low yield of the White Durra may be accounted for by losses through shattering and by attacks of



Fig. 3.—A plot of Dwarf Milo from selected heads. Note the large well-developed heads.

birds, 60 to 80 per cent of the grain usually being destroyed before it is mature.

Of the Kafirs the Dwarf Black-Hull Kafir gave the largest average yield, followed by Pink Kafir, Early Black-Hull, and Black-Hull White, respectively. The Dwarf and the Early Black-Hull are both more dwarfed in stature and earlier maturing than the Black-Hull White, and as grain crops are apparently better adapted to the conditions at Davis than the last named variety. The yield of the Pink Kafir has been fair, but it is very late in maturing and its seeds are rather dark and astringent, making it an undesirable variety to grow. The same in general may be said of the Red Kafir. The White Kafir, on the other hand, is a small, early maturing variety, but has little in its favor as a grain crop.

Of the Kaoliang group the best results have been obtained from Brown Kaoliang, though it must be stated that in manner and habit of growth, this variety and the Manchu Brown appear to be identical. Brachets Black-Hull Kaoliang, a rather dwarf, leafy variety, has given fair yields of grain during the two years it has been in the experiments. White Kaoliang, a very tall, though early maturing variety, is always attacked by birds, which accounts for its low yield.

The yield obtained from Shallu, it will be noted, is exceeded only by Dwarf Milo. This variety, however, was grown only during the last three years, giving it the advantage of the more favorable seasons.



Fig. 4.—Brown Kaoliang on the left, Dwarf Milo in the center, and White Kaoliang on the right.

It may be said, however, that the yield from Shallu is nearly always good and especially so when the supply of moisture is abundant. It is, however, later maturing and its seeds are small and hard, making them less desirable for feed than most of the other sorghums.

Considering the results as a whole the Durras have given higher yields than the varieties of any of the other groups, while the Dwarf Milo has been the most promising variety of the lot, and is without question the best variety for most conditions when a maximum yield of grain is desired. Regarding the other Durras, their relative worth will be determined by specific conditions and by the purpose for which they are to be grown. The yields of the Kafirs, on the whole

have been low, and it is questionable if they can be recommended for general use in this state except where grain and forage both are desired, and where the growing season is long.

A test including a few of the Durras and Kafirs was also conducted at the Kearney Park Station in 1913. In this test all the varieties were so badly injured by birds that the results were materially affected. An attempt was made to estimate the approximate percentage of injury in each case, which, together with the yields obtained, is given in Table II.

TABLE II
VARIETY TRIALS WITH GRAIN SORGHUMS
KEARNEY PARK, 1913

Variety	Per cent destroyed by birds	Yield per acre, pounds
Dwarf Milo	50	1739*
Standard Milo	60	1731*
White Durra	75	177†
Brown Durra	55	1817†
Feterita	40	1833
Dwarf Black-Hull Kafir	60	924
Early Black-Hull Kafir	60	770
Black-Hull White Kafir	50	429†

* Average of three plots.

† Average of two plots.

The results here obtained were practically the same as the averages of the four years at Davis. While Feterita gave a slightly higher yield than the Milos and Brown Durra, only one plot of the variety was grown, and it may be stated that the Dwarf Milo plot adjacent to the Feterita plot yielded 2285 pounds per acre or 450 pounds more than the Feterita. Furthermore the Feterita was not so much damaged by the birds as were the other varieties.

All the Kafirs gave low yields but the order of their importance as indicated by yield was the same at Kearney Park as at Davis.

CULTURE

Inasmuch as the grain sorghums are summer-grown crops, making their growth during the dry season of the year, too much emphasis cannot be placed upon the preparation of the seed bed and the care of the crop during the growing season. Especially is this important since the grain sorghums will, in most cases, be grown as a dry-land crop. We should not lose sight of the fact that although they are as a class drouth resistant, the yields which will be obtained will usually

be in direct proportion to the condition of the soil and the amount of moisture available. It is therefore desirable to handle the soil so that a good seed bed can be prepared and as much of the precipitation conserved as possible.

Preparation of the Seed Bed.—When possible the land should be plowed in the fall or early winter to a depth of eight or ten inches and allowed to lie in the rough until spring. In this condition the soil will absorb a large proportion of the winter rainfall and will also be materially benefited by weathering action. Unless the field is very weedy no further treatment will be necessary until it is to be prepared for seeding, at which time the seed bed can usually be prepared with a disc and harrow. If for any reason spring plowing becomes necessary it should always be more shallow than fall plowing, otherwise too much moisture will be lost by evaporation and difficulty will be experienced in working the land down properly for seeding. In fact, except on the most favorable soil more work is always required to prepare a good seed bed on spring-plowed than on fall-plowed land.

The seed bed should be smooth and even, with a mulch of two to three inches on the surface, while the soil below the mulch should be firm and moist. This condition is imperative as the seed of most of the grain sorghums is rather soft and rots easily if the soil is too cold or porous or the moisture supply insufficient for prompt germination. As has formerly been stated, such a seed bed can in most cases be prepared on fall-plowed land without difficulty with the ordinary implements found on the farm. Spring-plowed land, however, may require more work in order to pack the subsoil sufficiently and to pulverize the surface properly.

Time of Seeding.—The time to plant the grain sorghums will vary to some extent with the location and with the character of the soil. Planting should not be done until the soil and atmosphere are quite warm. In the valleys in the southern portion of the state where the warm weather begins early in the spring the crop may be planted earlier than in the north. Again, light, sandy soil warms up more quickly than heavy soil and can usually be planted a week to ten days earlier than the latter type. Results obtained at Davis indicate that in that section at least, the best time to plant is from the 10th to the 20th of April. If planted earlier the atmosphere and soil are too cold for the best growth. On the other hand, if planting is delayed until after the first of May the soil is apt to become too dry for prompt germination unless irrigation can be provided. On irrigated land seeding may be delayed until the middle or latter part of June, though the total yield will seldom be as great as when planting

is done earlier. In some places, however, this fact is made use of by employing the grain sorghums as a second crop to follow grain, grain-hay, or other similar spring crops.

Method and Rate of Seeding.—The most common method of planting the grain sorghums is to use a corn planter fitted with sorghum seed plates. With this implement the seed is drilled in rows three to three and one-half feet apart, spacing the seed from four to six inches apart in the row. In some cases the grain drill has been used for planting the crop by stopping up enough of the holes to give the proper spacing between rows. This implement, however, is not to be recommended as it seeds too shallow and too heavily for any but the most favorable conditions.

The distance commonly allowed between the rows is three and one-half feet, since this distance provides ample room for the development of the plants and for cultivation.

The distance between the plants in the rows will be governed by the character of the soil and the supply of moisture, and also by the variety employed. On fertile loam soils abundantly supplied with moisture, the heavier rates of seeding may be employed, while on sandy soils with a limited supply of moisture it is often advisable to allow a distance of even ten to twelve inches between the plants in the rows. Again, such short varieties as Dwarf Milo and others of the Durras can ordinarily be seeded heavier than such large leafy types as the Kafirs, since the individual plants do not require as much moisture or as much space for development as do the plants of the latter type. In the case of the Milos especially, it is usually advisable to seed as heavily as conditions will permit, otherwise the plants stool profusely, causing uneven development of the heads as well as uneven ripening. All of the Durras and some of the Kafirs, if provided with ample room, will stool to some extent, but none of them stool as prolifically as the Milo.

The amount of seed ordinarily required per acre will be from two to six pounds. When planting the sorghum crop care should be exercised to see that the seed is placed below the surface mulch in contact with moist soil where it may quickly absorb the water needed for germination. This will usually be at a depth of from two to three inches. If the seed bed is rough and open, however, as is often the case on spring-plowed land, deeper planting may be advisable, though the maximum depth on ordinary soil is probably about four inches. If planted too shallow, the seed will be placed in the dry mulch, where germination will be delayed, which will often result in a poor, uneven stand.

When the surface of the soil is rough and open or the layer of dry soil so deep that it is difficult to get the seed down to moisture, good results have often been obtained by attaching shovel furrow openers on the shoes of the planter. These shovels provide small furrows by pushing the clods and dry soil aside, thus making it much easier to get the seed down to the moist soil below. This provides a condition much the same as that obtained by listing, except that the furrows are smaller and much shallower, being no deeper than necessary to get the seed below the mulch.

Listing sorghums has not been practiced to any great extent in this state, though it probably could be employed to advantage especially on light soil or for late planting. When planted with a lister the seed is planted in the bottom of a furrow several inches below the normal level of the ground. This furrow is allowed to remain open until the plants attain some size, when it is gradually filled in by the successive cultivations. When planted by this method the main roots of the plants are forced to develop several inches below the surface of the soil, making it possible to maintain a deeper mulch without injuring the roots.

On soils that are heavy or wet, however, listing may be a disadvantage since the soil in which the seed is planted may be too cold for rapid germination, or the bottom of the furrow may bake so hard that the young plants will be unable to force their way through.

Care of the Crop.—The attention necessary after the crop has been planted will depend wholly upon the condition of the field and the season. The sorghums grow rather slowly at first, and it often happens that the field becomes foul with weeds before the plants are large enough to permit regular cultivation. When this occurs the weed growth may be destroyed by the use of a harrow without severe injury to the crop, provided the teeth are set at an angle of forty-five degrees. Again, if the soil becomes crusted due to rains, as frequently occurs on heavy soils, the crust must be broken as the young seedlings are often too weak to push their way through. If the crust is not too thick it may be broken with a harrow, though it is usually better to use a corrugated or dunham roller, as this implement breaks the crust without injury to the plants. In general it may be said, however, that either the harrow or the roller can be employed with safety until the plants attain a height of four or five inches.

As soon as the plants are large enough so that the rows can be plainly seen the field should be cultivated, using an ordinary two-horse corn cultivator. This cultivation should be at least four inches in depth as the main object beside the destruction of weeds is the

establishing of a deep mulch. For this purpose an implement with rather small shovels is to be preferred since it pulverizes the soil more thoroughly and leaves the surface relatively smooth and even. Two or three similar cultivations should be given at intervals of from two to three weeks or until the plants attain a height of about three feet, after which no further cultivation will be necessary. Normally the crop will continue growth and mature without further attention.

Irrigation.—While the larger proportion of the grain sorghum crop will probably be grown without irrigation, yet where water is available it can often be used to advantage and in some cases may be necessary. Especially is this true when the sorghum is to be grown as a second crop following grain-hay or some similar spring crop. In such cases it will nearly always be necessary to irrigate the land before seeding.

The time of irrigating and the number of irrigations after the crop has been planted will depend wholly upon the type of soil. Water should be applied when the plants appear to be affected by drouth. Except when the natural precipitation is very low one irrigation will usually be sufficient, this being applied when the plants start to head. Preirrigation on plowed land gives the best results when the soil is loamy and is well cultivated before the seed is planted.

For irrigating the sorghums the furrow method may be employed, but if the land has previously been leveled and checked, flooding is usually preferred because of the smaller amount of labor involved. After irrigation the field should be cultivated as soon as the soil is dry enough to work properly.

HARVESTING THE GRAIN CROP

The time of ripening will depend not only upon the time of planting, but also upon the location, and the season, as well as the variety. Where the average daily temperature is high the crop will mature much more quickly than where it is low or in sections having cool nights. For example, in the Imperial Valley or in the southern part of the San Joaquin Valley, Dwarf Milo will often mature in 100 to 115 days after the plants are up, whereas at Davis, where the nights are relatively cool, 125 to 140 days are normally required. A similar variation in the time of maturity has been noted with the varieties requiring a longer season.

The grain crop should not be harvested until the majority of the heads are fully mature, since immature seed is apt to heat in storage, causing a considerable loss. The common means of harvesting this crop is to cut the heads by hand, throwing them into a wagon and

hauling to the curing beds. By this method one man with a team can harvest from three-fourths of an acre to one acre per day, depending upon the character of the crop. Dwarf varieties with rather erect heads are sometimes harvested with a grain header. It is necessary, however, to modify the implement somewhat by raising the cutting device in order not to cut too much of the stalk. At best, some heads will be left in the field which must either be gathered by hand or pastured off by livestock. The corn binder is also employed to a slight extent, the stalks being cured in the field and later hauled to the barnyard and either headed or fed directly to livestock. Heading from the stack or shock by hand is much slower than heading from the standing crop. If the stalks are bound in bundles, however, they may be headed rather rapidly by laying the bundle on a block and cutting off the heads with a broadaxe or corn knife.

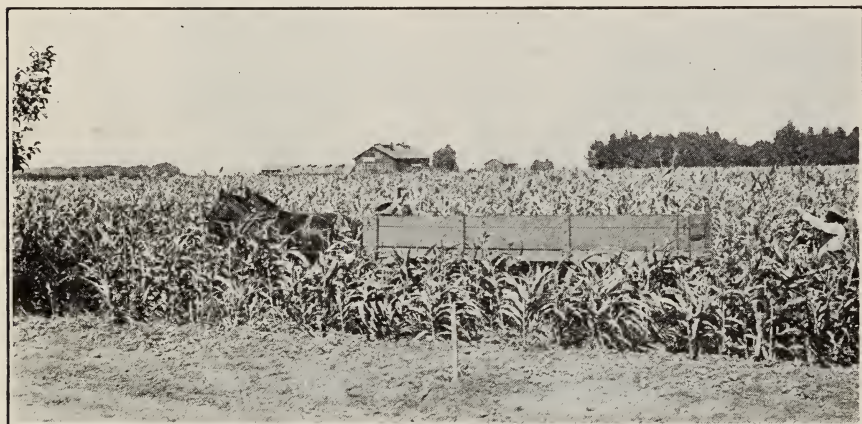


Fig. 5.—Harvesting Dwarf Milo at the University Farm.

After the heads are harvested they must be thoroughly cured. In sections where the conditions for drying are good the heads are usually placed in piles or ricks five to six feet in height, where they are allowed to remain for ten days, two weeks, or longer if necessary, until they are thoroughly dry. In sections where the conditions for drying are less favorable smaller piles must be used, otherwise the grains may spoil on the head. A method employed at the University Farm with good success is to spread straw on the ground to a depth of six to eight inches and then to spread the heads on the straw to a depth of a foot or eighteen inches, in which condition curing will take place rather quickly. When taken from the curing bed the straw is run through the thresher with the heads, thus preventing the usual loss due to shattering.

For threshing the grain sorghums, the ordinary grain thresher may be used if modified slightly. Most manufacturers of threshing machines supply special riddles to be used, which greatly facilitate the cleaning of the grain. The same riddles and sieves as are used for barley may be employed, though their use usually makes it necessary to reclean the seed after threshing. Another modification necessary is a removal of some of the concaves and a reduction in the



Fig. 6.—Threshing Milo at the University Farm.

speed of the cylinder, in order to prevent the cracking of a large percentage of the grains.

The grain is usually stored in bags rather than in bulk, since by this method it is easier to keep it from heating. Storing in bulk, however, may be practiced if it is kept perfectly dry and very large quantities are not placed in one bin. Because of the rather soft character of the seed, however, it absorbs moisture easily and will quickly spoil if not properly cared for. Even when placed in bags, they should be stored in as dry a place as possible, with ample circulation of air provided to keep the grain dry.

GRAIN SORGHUMS AS FORAGE CROPS

The grain sorghums have not as yet been used extensively for forage, though it has been shown that when employed as stover, fodder or silage they compare favorably with corn. The choice of varieties for this purpose will naturally differ somewhat from the selection for grain alone. In general, the varieties which produce the largest vegetative growth and are the most palatable should be employed. In many respects the Kafirs are to be preferred since they not only produce a high tonnage but their stalks are leafy, somewhat juicy and quite palatable. The Milos are also excellent for this purpose, being apparently equally palatable to the Kafirs, though the tonnage which they will produce will ordinarily be less. Such varieties as White and Brown Durras or Shallu, because of their dry, pithy stalks, and lack of leaves, yield a low tonnage of forage of very poor quality.

Unfortunately no extensive tests have been conducted to determine the relative forage yields of the different varieties. During the seasons 1914 and 1915, however, the total green weight produced by the more important varieties was determined by harvesting the whole plot as soon as the grain was mature and before the leaves had withered. The average yields of both grain and stalk, in tons per acre for the two years, of the varieties most suitable for forage purposes, were as follows:

	Tons per acre
Dwarf Milo	9.80
Standard Milo	9.93
White Milo	10.58
Feterita	7.01
Dwarf Black-Hull Kafir	12.35
Early Black-Hull Kafir	14.67
Black-Hull White Kafir	16.06

The cultural methods to employ when the crop is grown for forage are in most cases the same as those used for grain production. When the moisture supply is abundant it may be permissible, in most cases, to seed a little more heavily as by so doing the yield, as well as the quality of the forage, will be improved.

The proper time for harvesting will vary a little, depending upon the manner in which the forage is to be used; but since the stems and leaves of most of the grain sorghums remain green until after the seed is ripe, it is usually better to allow the seed to become mature before harvesting. If sorghums are to be used for silage this is

absolutely necessary in order to make the best quality of silage. If the product is to be fed as fodder the crop can be harvested when the seed is in the hard dough stage.

The sorghum forage crop may be harvested in exactly the same manner as corn. When the acreage is small, harvesting by hand or with a sled cutter will probably be most economical, but where large areas are to be handled it will usually pay to secure a corn binder which ties the plants into bundles, making them much easier to handle.

If the crop is to be used for silage it should be put into the silo as soon after cutting as possible, but if it is to be used as fodder the stalks or bundles should be put into shocks in the field and allowed to cure thoroughly, after which they may either be stacked or hauled directly to the feed rack.

GRAIN SORGHUMS IN THE ROTATION

The use of the grain sorghums in the rotation has been a rather perplexing problem since they have the unsavory reputation of being "hard on the land." Just why this crop is hard on the land is not definitely known, but it is true that if such a rapid growing crop as barley is seeded on the land immediately following grain sorghums the yield will not be so good as if preceded by some other crop. It is probable that the sorghum, the root system of which is bunched near the surface, draws heavily on the available plant food and moisture, thus lessening the supply for the crop immediately following, especially if that crop is one which demands these constituents in relatively large quantities. It is evident that as compared with Indian corn the grain sorghum leaves the soil in poor physical condition. Tests at the University Farm have shown, however, that if a couple of months elapse between the time the sorghum crop is removed and the seeding of the barley, the detrimental effect will be greatly lessened. When such a system is to be followed it is advisable to plow up the sorghum stubble as soon as the crop has been removed as areation will then be more thorough and the injurious effect more readily overcome. Wheat and oats are not affected as much as barley, while intertilled crops seem to be affected even less.

Another problem that will arise is the proper disposition of the stalks when they cannot be used for feed. While definite information is lacking as to the best means to dispose of them, it will probably be best to cut and remove them from the field, especially in sections where the moisture supply is low. While the writer is aware that this is contrary to the best agricultural teaching, yet it has been

found that with a low rainfall the soil moisture will be insufficient to rot so large a quantity of material and trouble will follow. Even when the stalks are removed, difficulty will sometimes be experienced in disposing of the stubble and roots. By using a fourteen or sixteen-inch mouldboard plow, however, the stubble may be turned under with a fair degree of success, but the ten or twelve-inch plows commonly found on California farms are too small to perform the job in a satisfactory manner. If the plowing is done in the fall or early winter, the large crowns will ordinarily be sufficiently disintegrated by spring so that they will not cause trouble when preparing for most spring crops. Sorghum, however, is not a good crop to precede alfalfa as even under the most favorable conditions the roots and stubble are apt to prove troublesome in leveling and checking the land as well as in seeding the alfalfa.

The grain sorghums may apparently follow almost any other crop with fair success, though it is not advisable to grow this crop on the same land year after year without the use of some other crop in the rotation. A system which is finding some favor where irrigation is available is to utilize the grain sorghum as a second crop following grain hay. The hay crop is removed in May or early June and the land irrigated and plowed and planted to sorghum. For this purpose an early maturing variety, such as Milo, White Durra, or Feterita, should be employed to avoid the possible danger of the crop being injured by frost before maturity. Even these varieties can not be planted later than the 20th of June without incurring the possible danger of injury by frost before maturity takes place in most sections of the state.

SEED SELECTION AND IMPROVEMENT

As yet but little effort has been made to improve the grain sorghums, though from the small amount of work that has been done it is apparent that a great deal of progress can be made in this direction. By intelligent selection the yield of grain and forage may be greatly increased, as may also the earliness of maturity and drouth resistance. With such varieties as the Milos, which normally have rather pendent heads, it is possible, through careful selection, to develop in a very short time a strain with perfect heads. Many other similar lines of improvement will naturally suggest themselves, but the grower should bear in mind that it is much more difficult to fix several characters than one or two, for which reason only such characters should form the basis of selection as will be of value under his particular conditions.

While the majority of growers may not care to attempt improvement of the crop as above suggested, all are strongly urged to maintain seed plots, especially if they desire to grow the crop year after year. This is especially desirable as the seed on the market is often badly mixed with other varieties as well as badly hybridized with these varieties.

Inasmuch as all varieties of sorghums cross rather readily the seed plot should be maintained in an isolated part of the field where it will not be crossed by other varieties. The seed for this plot should be from heads or plants of a uniform type, for by careful selection of the few heads necessary to plant the seed plot, the grower is able not only to purify his strain, but to increase the yield and quality of his product as well.

VALUE AS FEED

Relatively little information is available concerning the feeding value of the grain sorghums, especially as compared with the other cereals, but such tests as have been conducted indicate that when fed either as grain or in the form of fodder or silage they compare favorably with Indian corn. It should be remembered, however, that the grain of the sorghums, like that of the other cereals, is not in itself a balanced ration, and will, therefore, give the best results only when fed in conjunction with some more concentrated nitrogenous feed.

In order to determine the relative composition of the different varieties analyses were made on the grain of the 1914 crop, the results of which, together with the analyses of corn and barley, are given in table III.

Comparing the average composition of all the grain sorghums with corn and barley it will be noted that they are but slightly lower in protein, fat, and crude fiber than corn, but higher in carbohydrates and ash. Barley is somewhat higher in protein, crude fiber and ash, but considerably lower in fat and carbohydrates.

A rather wide variation in the composition of the different varieties was obtained, but attention is called to the fact that the data given in the table represent but one analysis of each variety, and perhaps, therefore does not give an accurate comparison under all conditions.

As a grain feed, it is pretty well understood that there is some difference in value between the different types and varieties not shown in the composition. The Brown Durra and the Kafirs, for instance, are prone to have a constipating effect on the digestive system of animals unless fed with a laxative feed, such as linseed meal, cocoanut meal or alfalfa.

TABLE III
COMPOSITION OF GRAIN SORGHUMS¹
1914 CROP

Variety	Per cent					
	Water	Protein	Fat	Crude fiber	Carbo-hydrates	Ash
<i>Durras</i>						
Dwarf Milo	10.05	8.99	3.35	1.91	74.25	1.45
White Milo	11.75	8.31	2.85	1.73	73.86	1.50
White Durra	11.00	10.58	3.62	1.30	71.36	2.14
Brown Durra	11.30	10.75	3.18	1.60	71.28	1.85
Feterita	11.35	9.49	2.12	1.33	74.21	1.50
Average all Durras	11.09	9.62	3.02	1.58	72.99	1.69
<i>Kafirs</i>						
Dwarf Black-Hull Kafir	11.82	9.66	3.90	2.13	70.69	1.80
Red Kafir	12.75	9.49	3.10	1.68	71.32	1.66
Pink Kafir	12.74	9.32	3.28	2.37	70.35	1.49
Average all Kafirs	12.44	9.49	3.43	2.06	70.79	1.65
<i>Kaoliangs</i>						
White Kaoliang	10.82	11.68	3.90	2.45	68.59	2.56
Manchu Brown Kaoliang ..	9.78	9.32	3.71	1.33	74.48	1.38
Brown Kaoliang	10.19	10.25	3.36	1.75	72.27	2.18
Brachets Black-Hull Kao- liang	12.35	9.66	3.20	2.41	70.33	2.05
Average all Kaoliangs	10.78	10.23	3.54	1.98	71.42	2.04
Shallu	12.85	9.28	3.93	1.63	70.74	1.57
Average all sorghums	11.44	9.76	3.34	1.76	71.82	1.78
Indian corn ²	10.60	10.30	5.00	2.20	70.40	1.50
Barley ³	10.90	12.40	1.80	2.70	69.80	2.40

¹ Analyses of sorghums made by Professor M. E. Jaffa.

² and ³ Taken from Jordan's "Feeding of Farm Animals."

With the White Durra and the Milos, however, no effect of this character has been noted, a fact which renders them especially desirable as calf or poultry feeds. When the sorghums are used as grain feed much better results will usually be obtained if the seed is ground or crushed than if fed whole. When fed to livestock good results are also obtained by grinding or crushing the whole heads. The feed thus obtained compares favorably with corn and cob meal.

For fodder or silage purposes the value as a feed is governed to some extent by the variety and by the time of harvesting. However, where properly handled the fodder or silage from the Kafirs or Milos is but slightly inferior to corn. Much still remains to be learned, not only with regard to the value of the sorghums as feed, but also with regard to the most economical means of feeding them. When these problems have been more fully worked out and the value of the crops

as feed better understood it will doubtless lend a strong impetus to the production of this crop.

Danger from Poisoning.—Considerable apprehension is felt regarding the danger to stock from poisoning where the sorghums are fed green. It is true that plants which have been stunted in their growth sometimes develop prussic (hydrocyanic) acid in their leaves, which is quickly fatal to the animals which eat it. Most of the loss from poisoning, however, has occurred by pasturing stock on second-growth sorghums after the first crop has been removed. This second growth is made at a season of the year when the soil is dry and the conditions for growth not wholly favorable. The first growth seldom, if ever, causes trouble and can be either pastured or fed green without danger. In curing, the prussic acid disappears, so there is absolutely no danger in feeding the dry stover or fodder.

ENEMIES OF THE GRAIN SORGHUMS

The grain sorghums grown in this state have been remarkably free from pests, either in the form of insects or diseases. The sorghum kernel smut is sometimes met with, but seldom is the infection bad enough to occasion great loss. Head smut of sorghum has recently appeared in the state. This smut greatly reduces the plant growth and wholly prevents the formation of seed. Seed from such fields should not be planted. Both smuts can be controlled by soaking the seed for fifteen minutes in hot water (132° to 134° F.). Kernel smut may be prevented by dipping for thirty minutes in a solution of formaldehyde (one pound of formaldehyde to thirty gallons of water). After treatment the seed should be dried immediately and seeded as soon as possible. It is stated⁴ on good authority that the Dwarf and Yellow Milo are immune to this disease.

Undoubtedly the most destructive pest of the grain sorghums in this state are blackbirds, and their control is not only difficult but probably impossible. Some of the varieties, such as White Durra and the White Kafir, are apparently preferred by the birds, but the other varieties are by no means immune to their attacks. This preference is sometimes made use of by planting a few rows of the varieties desired by the birds around the main field as a trap crop to attract the birds from the main portion of the field. It is necessary, however, to use a variety which matures as early as the main crop, the White Durra probably being the variety most commonly used.

⁴ Farmers' Bulletin 288, p. 26.

SUMMARY

1. The first introduction of grain sorghums into the United States occurred in 1874 when White and Brown Durra were brought to California from Egypt. Since that date their production in this state has increased gradually until in 1919, 170,000 acres were planted.

2. Sorghums prefer a warm, dry climate, relatively low in humidity. Localities with relatively cool conditions during the growing season are least suited to the growth of this crop.

3. The grain sorghums will withstand more drouth than most other field crops grown in California. However, since they are summer-grown crops, they must depend upon the water stored in the soil for their moisture supply. For this reason free-working loam soils with a large water-holding capacity are to be preferred.

4. Variety tests at the University Farm at Davis indicate that Dwarf Milo is the best variety for grain. All the Durras, however, are more prolific grain producers than the Kafirs.

5. In preparing the field for sorghums the land should be plowed in the fall or early winter to facilitate the absorption of moisture and the subsequent preparation of the seed bed. A well-prepared seed bed is necessary for sorghums in order to insure prompt germination of the seed.

6. The grain sorghums should not be planted until the soil and atmosphere are quite warm. At the University Farm the best results were obtained by planting between the dates of April 10 and 20. The corn planter fitted with sorghum seed plates is the implement commonly employed for planting the crop.

7. The amount of seed required per acre will vary from two to six pounds, depending upon conditions. The distance between the rows and the rate of planting in the row must be governed by the variety and the amount of moisture available.

8. Listing sorghums has not been practiced to any great extent but may be advantageous on light dry soil or for late planting.

9. After the plants come up they should be cultivated often enough to keep the weeds in check and to maintain the mulch.

10. Grain sorghums are usually harvested by hand although the grain header or the corn binder may be employed. After harvesting it is necessary to cure the heads thoroughly before threshing, as the seed is otherwise apt to heat in storage.

11. For forage purposes the Kafirs and Milos, because of their juicy stems, are preferable to most of the other varieties. In using

the grain sorghums for silage the seed should be allowed to mature before harvesting in order to secure the best quality of silage.

12. Grain sorghums are hard on the soil and are not a good crop to precede such a rapid-growing crop as barley. This effect, however, can be largely overcome by plowing the field and allowing it to lie idle for a couple of months before seeding to another crop. Early maturing varieties of grain sorghums may be used as a second crop to follow grain hay.

13. Grain sorghums when fed either as grain fodder or silage are but slightly inferior to Indian corn in feed value. Second-growth sorghums may develop prussic acid, which is poisonous to stock; the first crop, however, seldom if ever develops poison, nor is this found in the dry forage.

14. The worst enemies of grain sorghums in California are black-birds, against which no adequate means of control have been devised.

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